NFIQ 2.0 – Features for fingerprint quality determination

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May 4, 2016

Outline

Introduction

- Starting point for features
  - NFIQ 1.0
  - ISO/IEC TR 29794-4:2010
  - Literature

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- Workshops central to development of features

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$$\begin{aligned}\mathbf{Q}_{\text{NFIQ 2.0}} = \Big(& Q^{\mu}_{\text{FDA}}, Q^{\mu}_{\text{LCS}}, Q^{\mu}_{\text{OCL}}, Q^{\mu}_{\text{OFL}}, Q^{\mu}_{\text{RVU}}, \\ & Q^{\sigma}_{\text{FDA}}, Q^{\sigma}_{\text{LCS}}, Q^{\sigma}_{\text{OCL}}, Q^{\sigma}_{\text{OFL}}, Q^{\sigma}_{\text{RVU}}, \\ & \mathbf{Q}_{\text{FDA}}, \mathbf{Q}_{\text{LCS}}, \mathbf{Q}_{\text{OCL}}, \mathbf{Q}_{\text{OFL}}, \mathbf{Q}_{\text{RVU}}, \\ & Q_{\text{MU}}, Q_{\text{MMB}}, Q^{rel}_{\text{COH}}, Q^{sum}_{\text{COH}}, Q^{\mu}_{\text{AREA}}, \\ & Q^{cnt}_{\text{MIN}}, Q^{com}_{\text{MIN}}, Q^{mu}_{\text{MIN}}, Q^{ocl}_{\text{MIN}} \Big) .\end{aligned}$$

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- Local quality at minutiae locations
- Mean and standard deviation of local features
- Histogram of local features (boundaries determined from CDF)
- Classifier
  - Random Forest trained for binary classification
  - Input: 69 dimensional feature vector
  - Output: probability of input being Class 1 (high utility) quantized $[1, 100]$

NFIQ 2.0 Quality features

Name	Capture mode	Type	Number of subjects	Fingers	Number of comparisons per finger	Used for
AZLA	Scanned ink	Operational	240,000	Index and Thumb	120,000 mated. 120,000 non-mated	training + testing
POEBVA	Live scan	Operational	180,000	Index	120,000 mated. 120,000 non-mated	training + testing
VISITIDF	Live scan	Operational	220,000	Index and Thumb	95,000 mated. 120,000 non-mated	training + testing
DHS2	Live scan	Operational	180,000	Index	120,000 mated. 120,000 non-mated	training + testing
IQMI	Scanned ink	Operational	250,000	10 fingers	250,000 mated. 250,000 non-mated	testing
BKA	Live scan	Operational	342,000 images	10 fingers	—	testing
BKA	+ Scanned ink					
SD 29	Scanned ink	Public	209	10 fingers	1912 mated. 35,791 non-mated	testing
FVC 2000 DB1	Live scan	Public	110	8 fingers	—	compliance testing
FVC 2000 DB3	Live scan	Public	110	8 fingers	—	compliance testing
FVC 2002 DB1	Live scan	Public	110	8 fingers	—	compliance testing

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- Data from operational sources (Optical sensors)
- Training set 6629 images (3295 in Class 0 and 3334 in Class 1)
- Validation set 99797 randomly selected images
- External validation on BKA data and FBI data

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  1. NFIQ=1 ($S_{act} > 0.7$) and S_{gen} in 90th percentile
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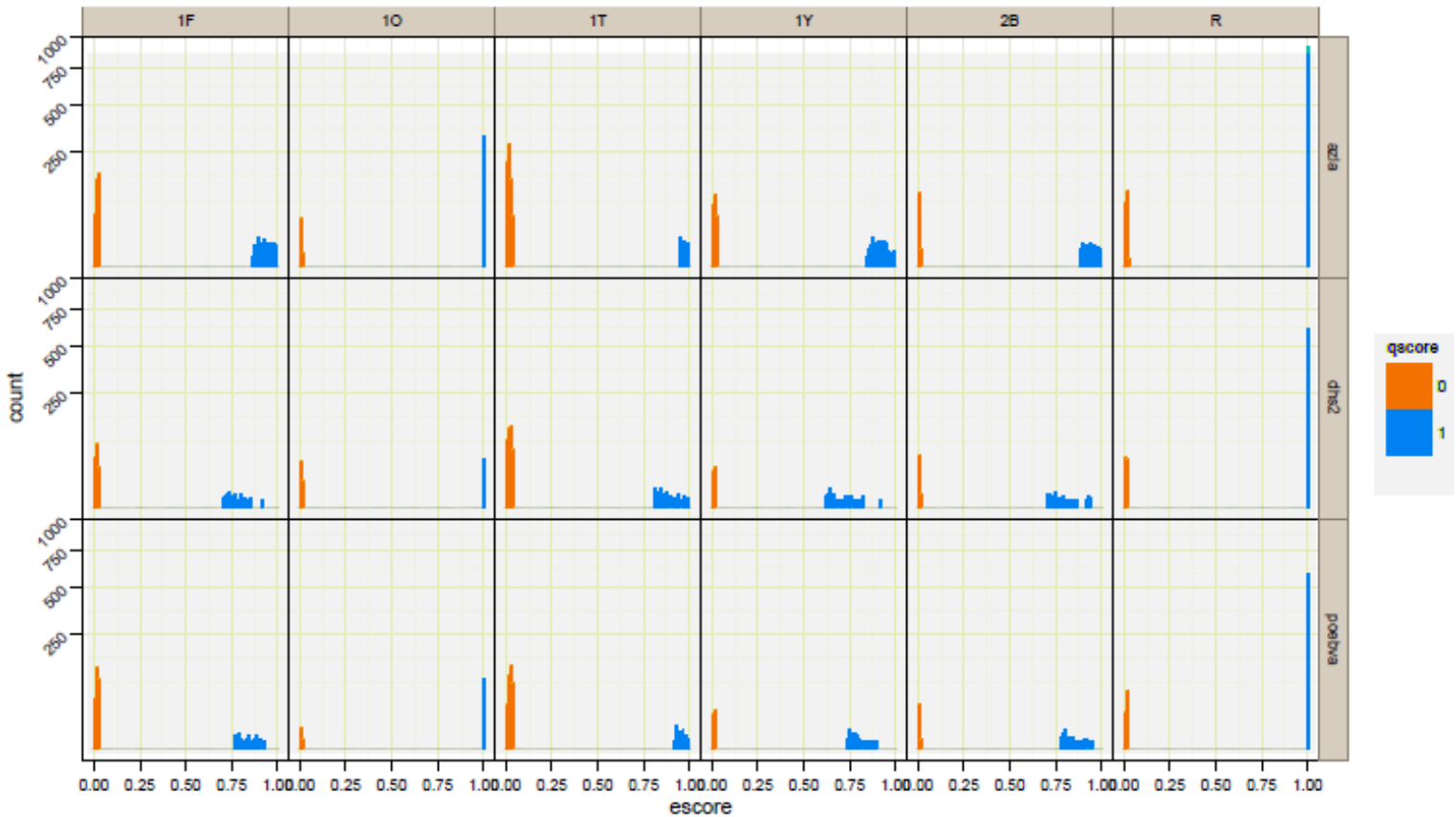


NFIQ 2.0 Quality features

Feature importance ranking

	Name	MeanDreaseGini
Q^{σ}_{FDA}	Frequency Domain Analysis_Standard Deviation	140.760
Q^{com}_{MIN}	FingerJet FX OSE COM Minutiae Count	92.089
Q^{ocl}_{MIN}	FingerJet FX OSE OCL MinutiaeQuality	83.027
Q^{μ}_{RVU}	Ridge Valley Uniformity_Mean	69.517
Q^{μ}_{FDA}	Frequency Domain Analysis_Mean	62.229
Q^{cnt}_{MIN}	FingerJet FX OSE Total Minutiae Count	57.565
Q^{σ}_{RVU}	Ridge Valley Uniformity_Standard Deviation	50.946
Q^{7}_{LCS}	Local Clarity Score_Bin_7	50.688
Q^{8}_{LCS}	Local Clarity Score_Bin_8	50.100
Q^{9}_{FDA}	Frequency Domain Analysis_Bin_9	47.844
Q^{sum}_{COH}	ROI Orientation Map Coherence Sum	38.104
Q^{2}_{OFL}	Orientation Flow_Bin_2	37.172
Q^{μ}_{LCS}	Local Clarity Score_Mean	36.483
Q^{5}_{RVU}	Ridge Valley Uniformity_Bin_5	35.617
Q^{3}_{RVU}	Ridge Valley Uniformity_Bin_3	35.139
Q^{μ}_{AREA}	ROI Area Mean	34.932
Q^{1}_{OFL}	Orientation Flow_Bin_1	33.751
Q^{0}_{OFL}	Orientation Flow_Bin_0	33.513
Q_{MU}	MU	32.914

Quality feature example - frequency domain analysis

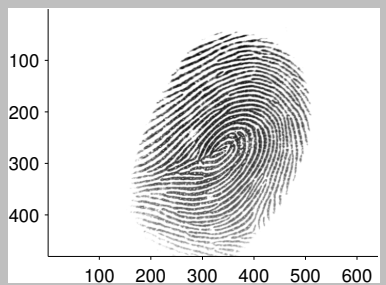
- Q_{FDA} local determination of ridge-valley signature

Algorithm 3: fda algorithm

Input: Fingerprint image **I**
Output: fda quality score Q_{FDA}

```
for each block V in I do
    pad V with 2 pixel around border
    rotate V with nearest neighbour interpolation such that dominant ridge flow is perpendicular to x-axis
    crop V such that no invalid regions are included
    with V obtain the ridge-valley signature T (eq. (11))
    compute the dft of T to obtain the magnitude representation A
    discard the first component of A
    determine F_max as the index of the largest magnitude in A
    compute Q_FDA^local of V using A and F_max (eq. (12))
end
```

Quality feature example - frequency domain analysis



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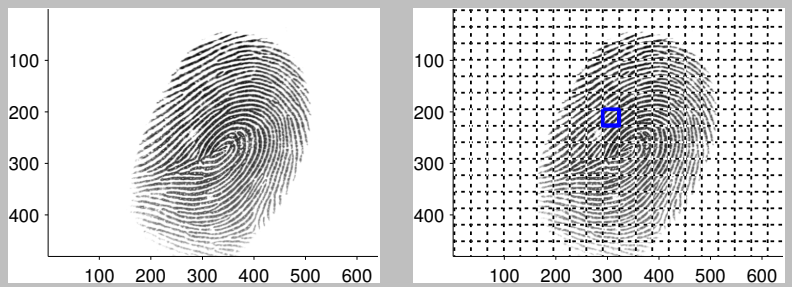

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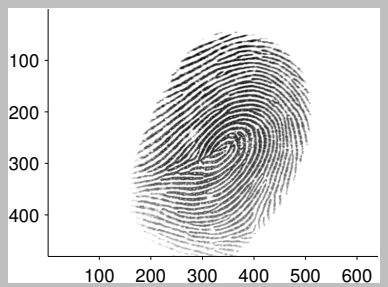

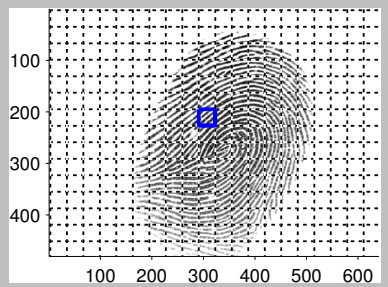

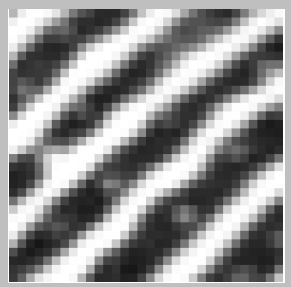

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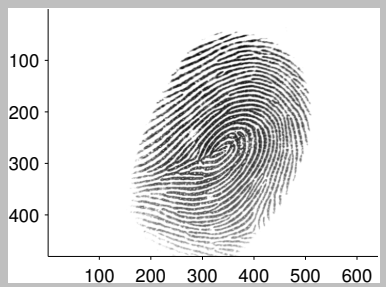

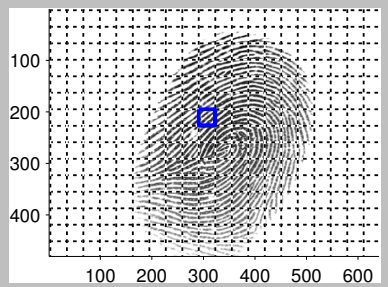

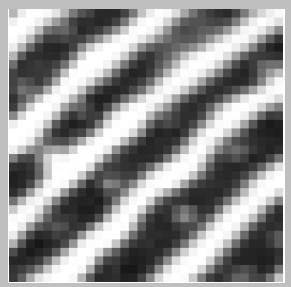

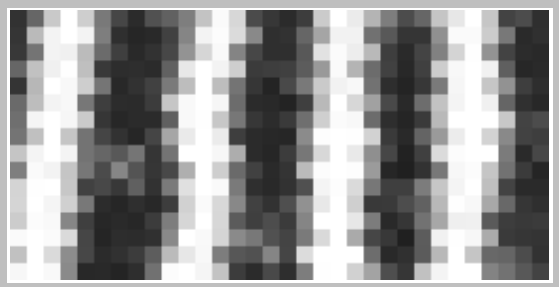

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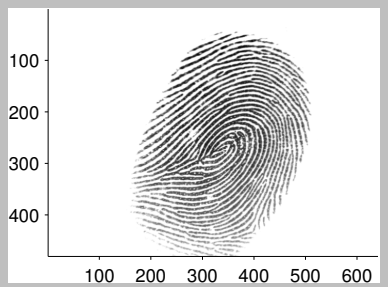

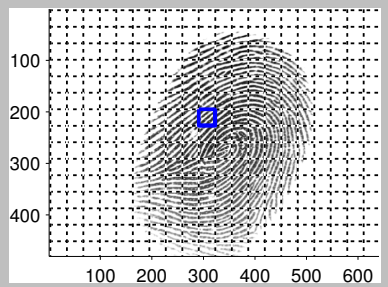

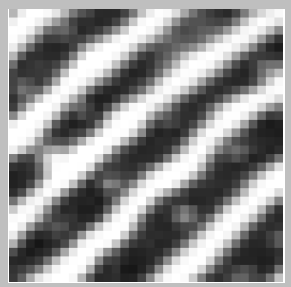

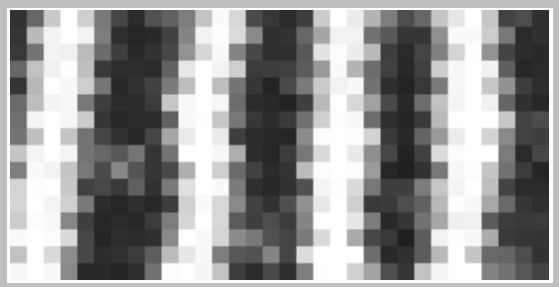

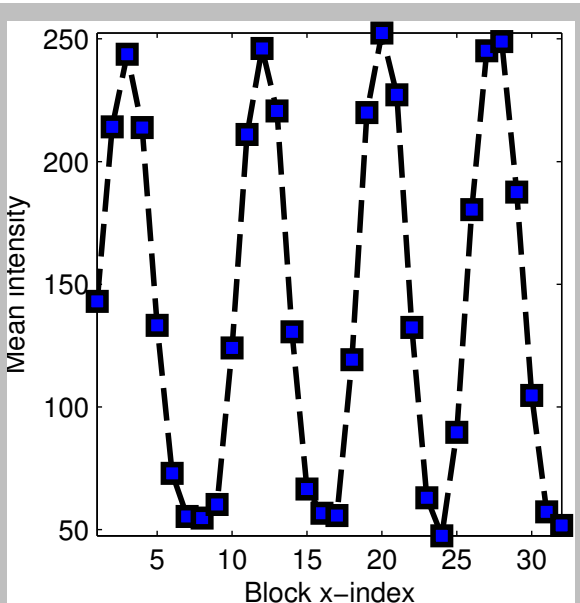

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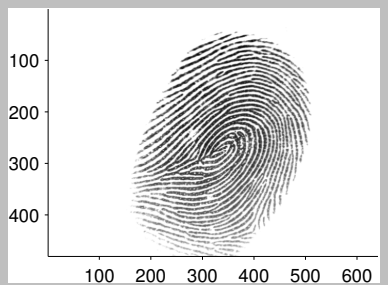

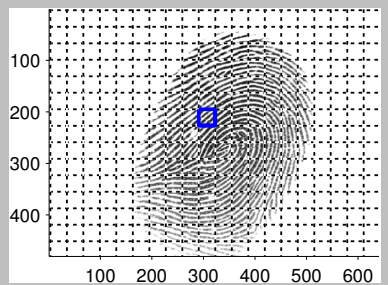

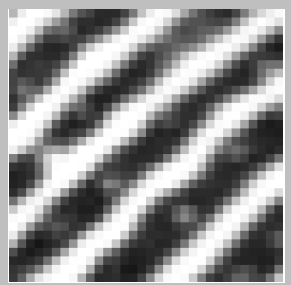

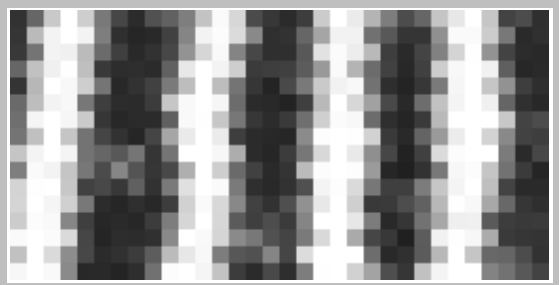

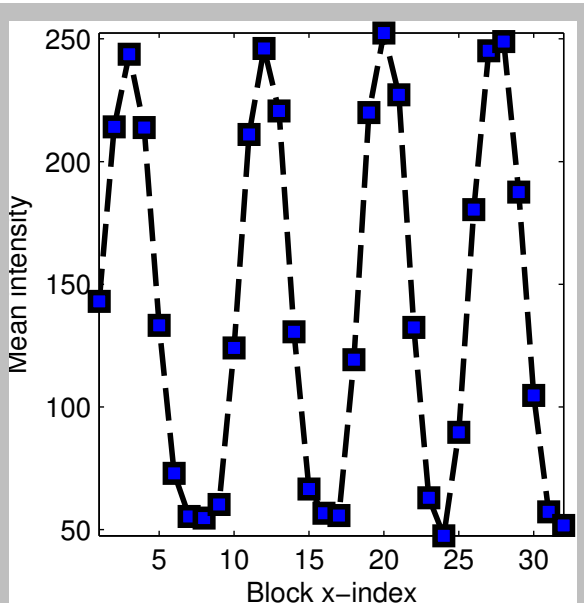

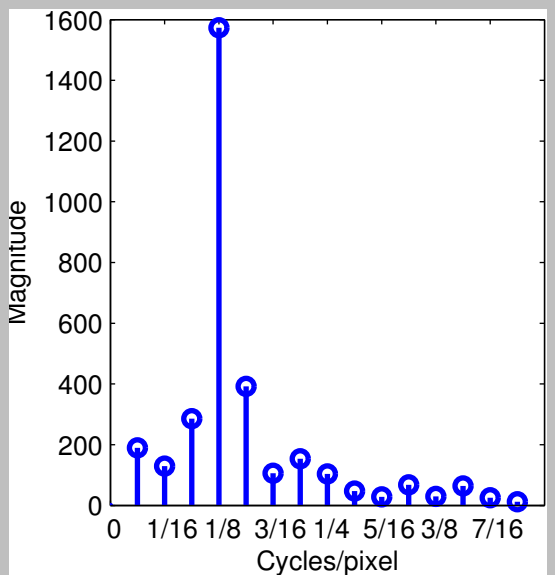

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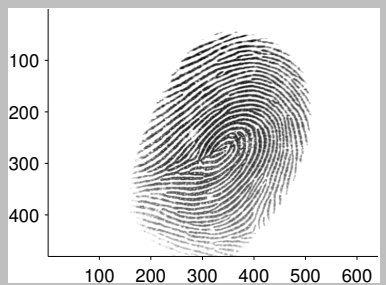

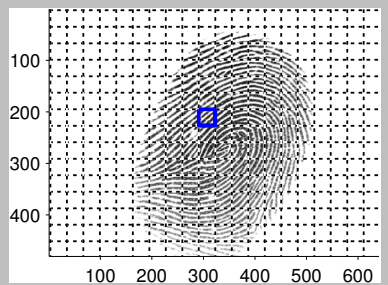

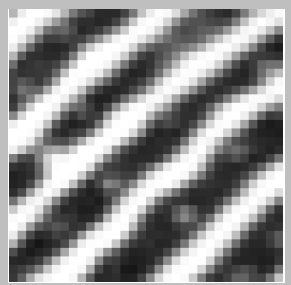

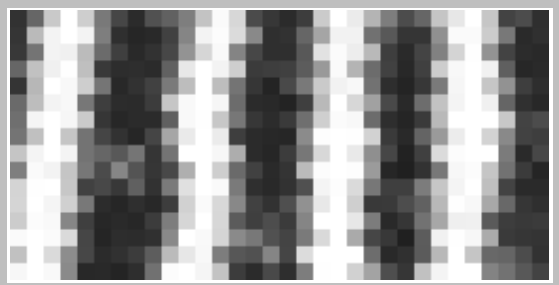

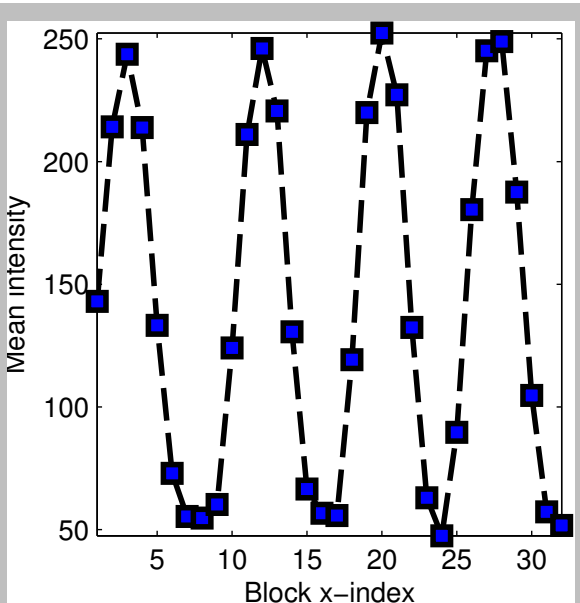

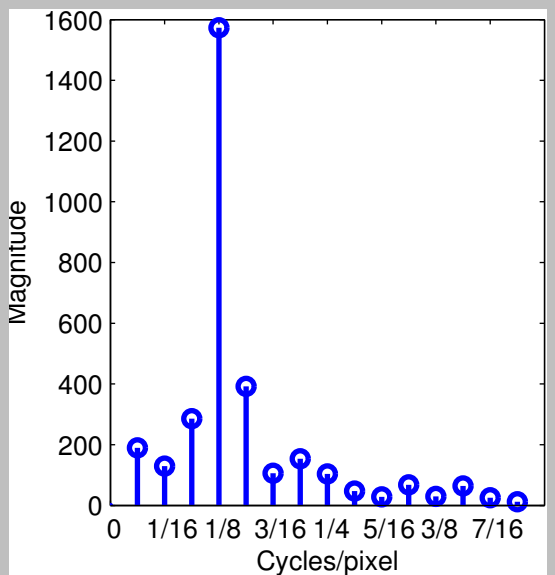

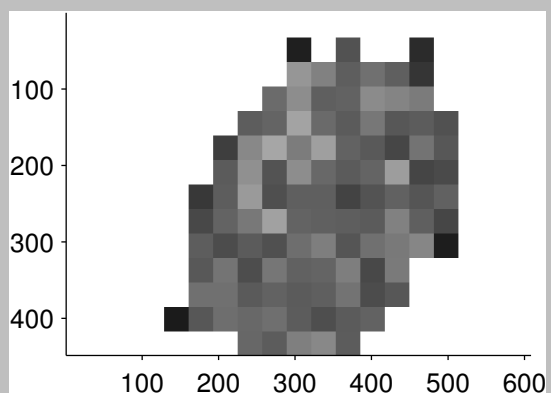

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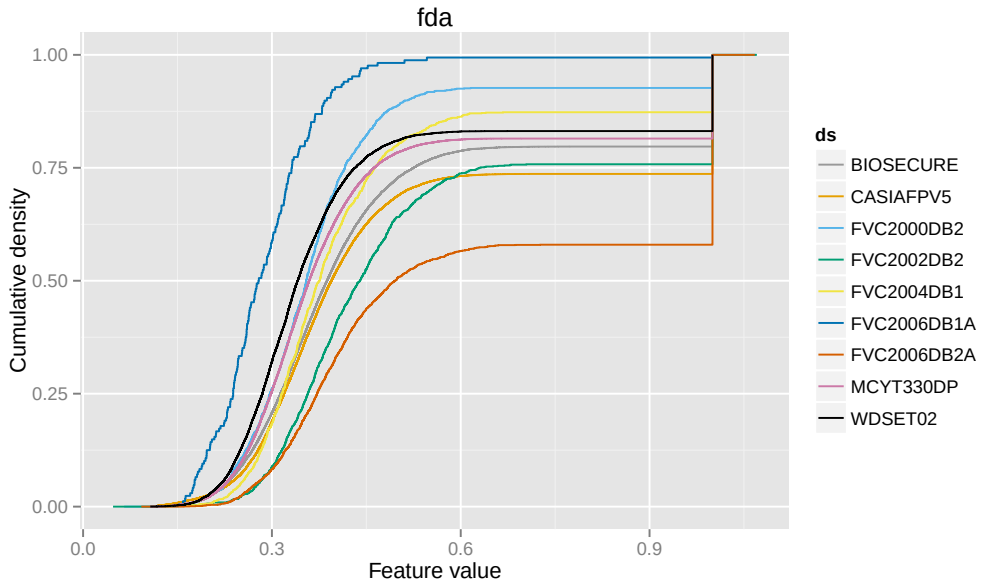

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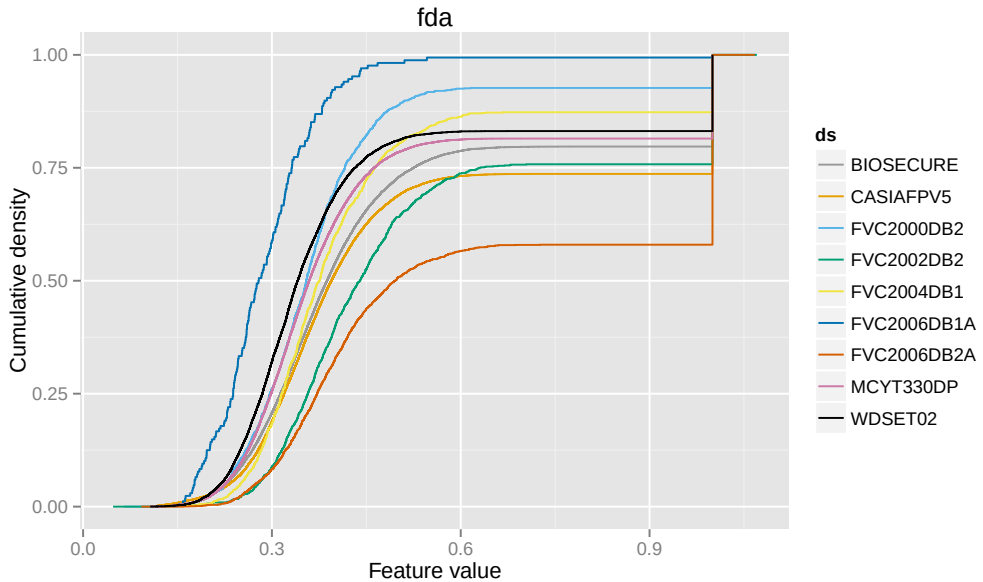

$$B_{\text{FDA}} = \{-\infty, 0.26800, 0.30400, 0.33000, 0.35500, 0.38000, 0.40700, 0.44000, 0.50000, 1.00000, \infty\}.$$

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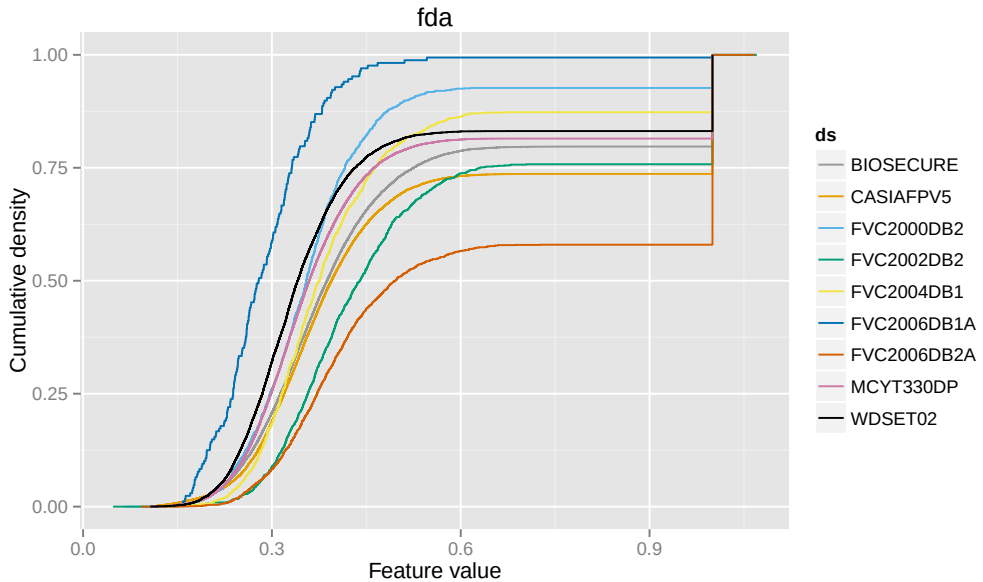

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- Local quality values $\Rightarrow$fixed length feature vector
- Mean, std.dev., 10 bin histogram $\Rightarrow$12-dimension feature vector

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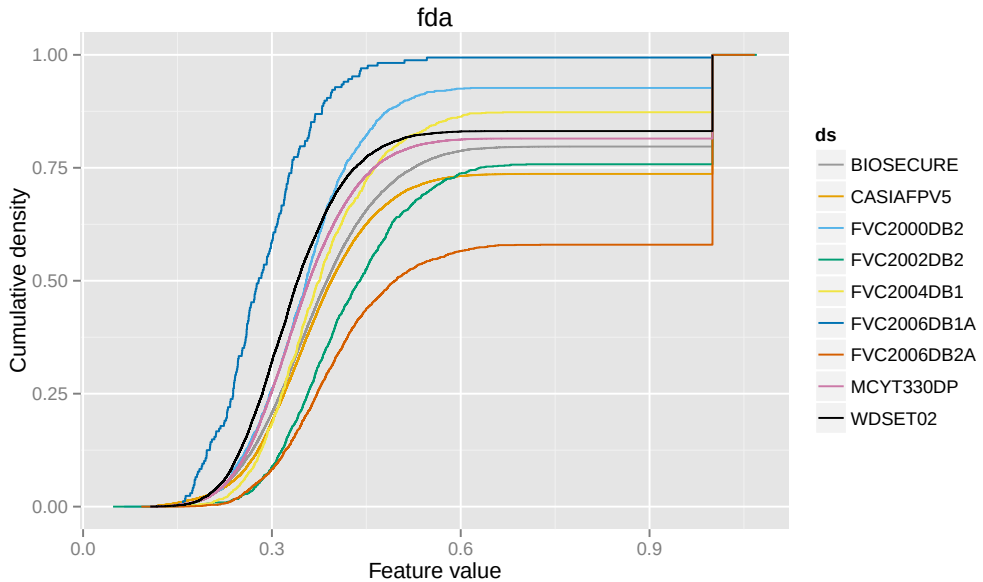

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$$Q_{\text{FDA}} : \{Q^{\mu}_{\text{FDA}}, Q^{\sigma}_{\text{FDA}}, Q^{1}_{\text{FDA}}, \ldots, Q^{10}_{\text{FDA}}\}$$

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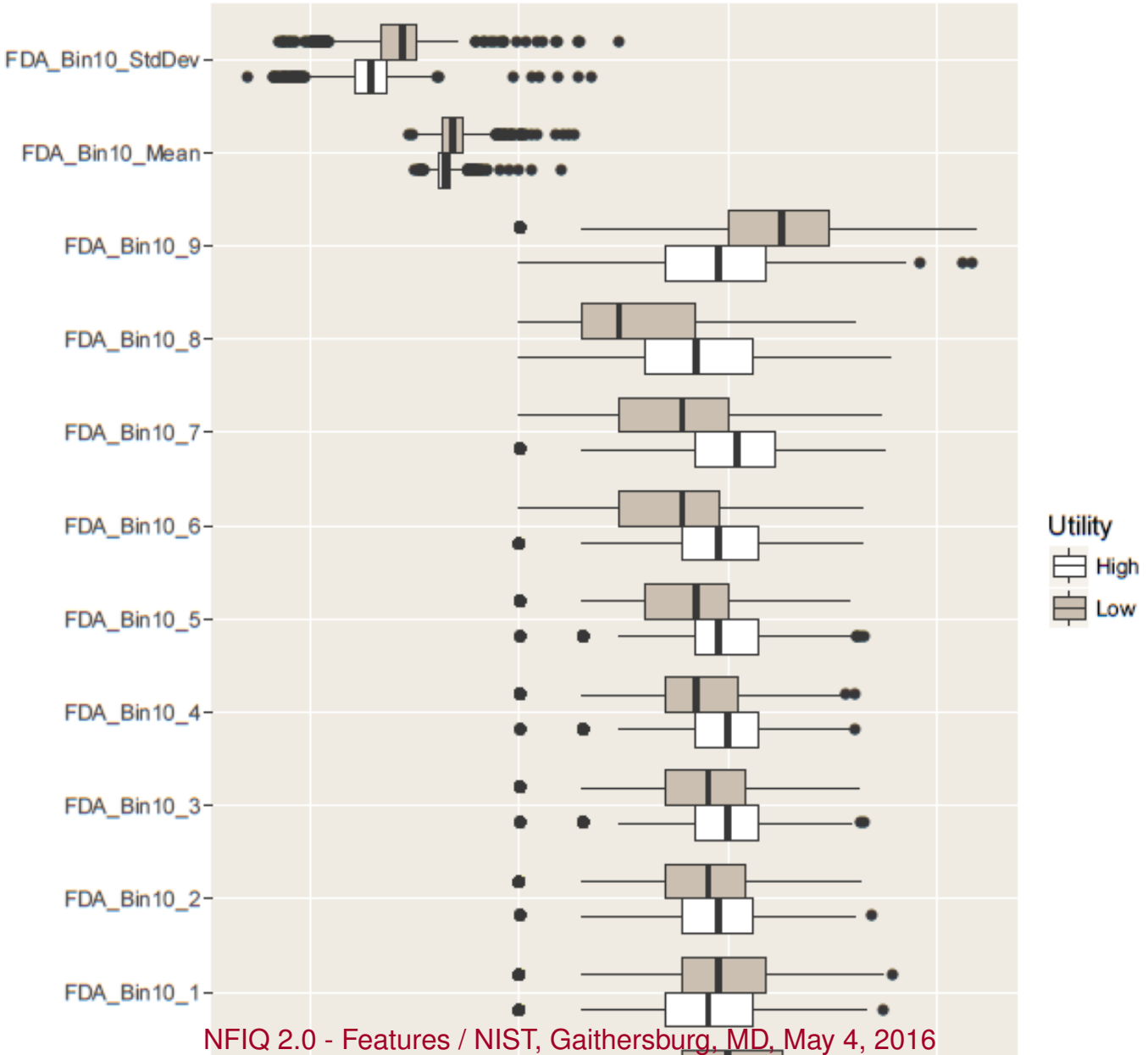

Speeding up NFIQ 2.0

- Request ⇒near frame rate quality assessment (10 Hz)

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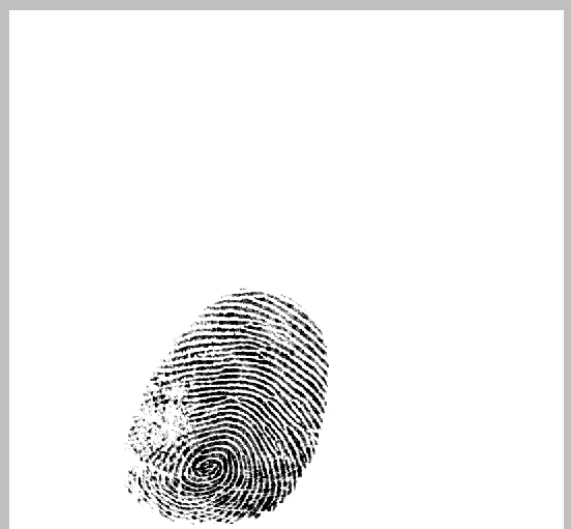
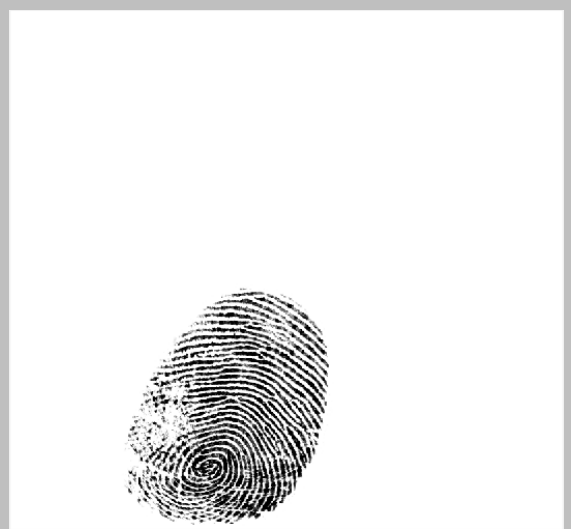


800×750 pixel sensor output reproduced at 25% scale

Speeding up NFIQ 2.0

- Request ⇒near frame rate quality assessment (10 Hz)
- Slap sensors provide large finger images
- Removal of near constant area
- No processing of background area blocks



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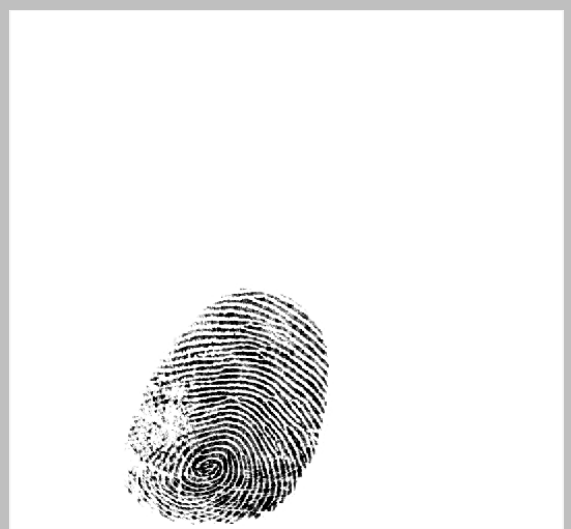
Speeding up NFIQ 2.0

- Request $\Rightarrow$near frame rate quality assessment (10 Hz)
- Slap sensors provide large finger images
- Removal of near constant area
- No processing of background area blocks
- Avoid removing low quality fingerprint areas



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$330 \times 286 = 94380$
(15.7%)

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(15.7%)

$330 \times 286 - (10 \times (32 \times 32)) = 84140$
(13.9%)

Actionable feedback

- Demand for actionable feedback from quality algorithm
- More than a quality score - helps to answer the why
- Provide information $\Rightarrow$improve quality at recapture

Actionable feedback

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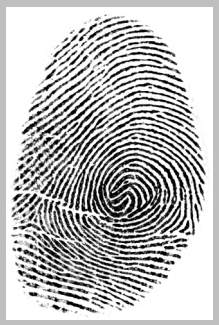
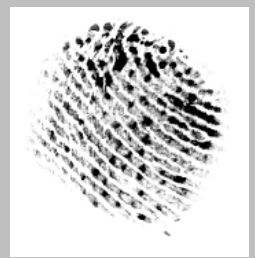
- More than a quality score - helps to answer the why
- Provide information $\Rightarrow$improve quality at recapture
- Finger image receives low quality score - why?





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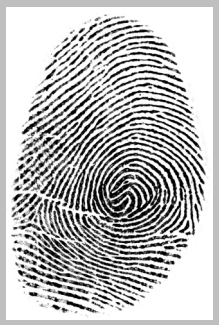

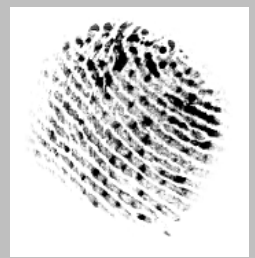

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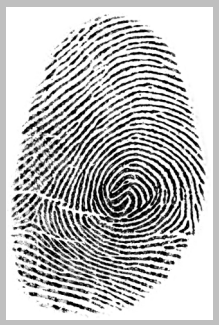

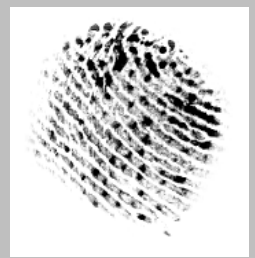

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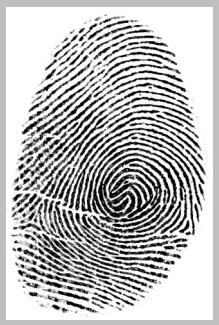
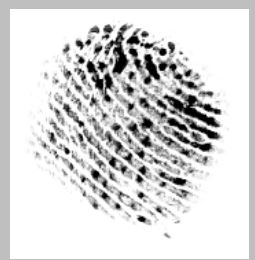
  - empty image ($\mu > 250$)
  - uniform image pixel intensity ($\sigma = 1.0$)
  - no or few minutiae detected ($N_{min} < 5$)
  - small foreground area ($N_{fgrnd} < 50000$)





Actionable feedback

empty image	$\mu > 250$	uniform image intensity	$\sigma = 1.0$
few minutiae	$N_{min} < 5$	small foreground	$N_{fgrnd} < 50000$

NFIQ 2.0 = 89

$\mu = 177$

$\sigma = 99$

$N_{min} = 60$

$N_{fgrnd} = 117337$

Actionable feedback

empty image	$\mu > 250$	uniform image intensity	$\sigma = 1.0$
few minutiae	$N_{min} < 5$	small foreground	$N_{fgrnd} < 50000$

NFIQ 2.0 = 21

$\mu = 220$

$\sigma = 64$

$N_{min} = 40$

$N_{fgrnd} = 36887$

Actionable feedback

empty image	$\mu > 250$	uniform image intensity	$\sigma = 1.0$
few minutiae	$N_{min} < 5$	small foreground	$N_{fgrnd} < 50000$

NFIQ 2.0 = 1

$\mu = 196$

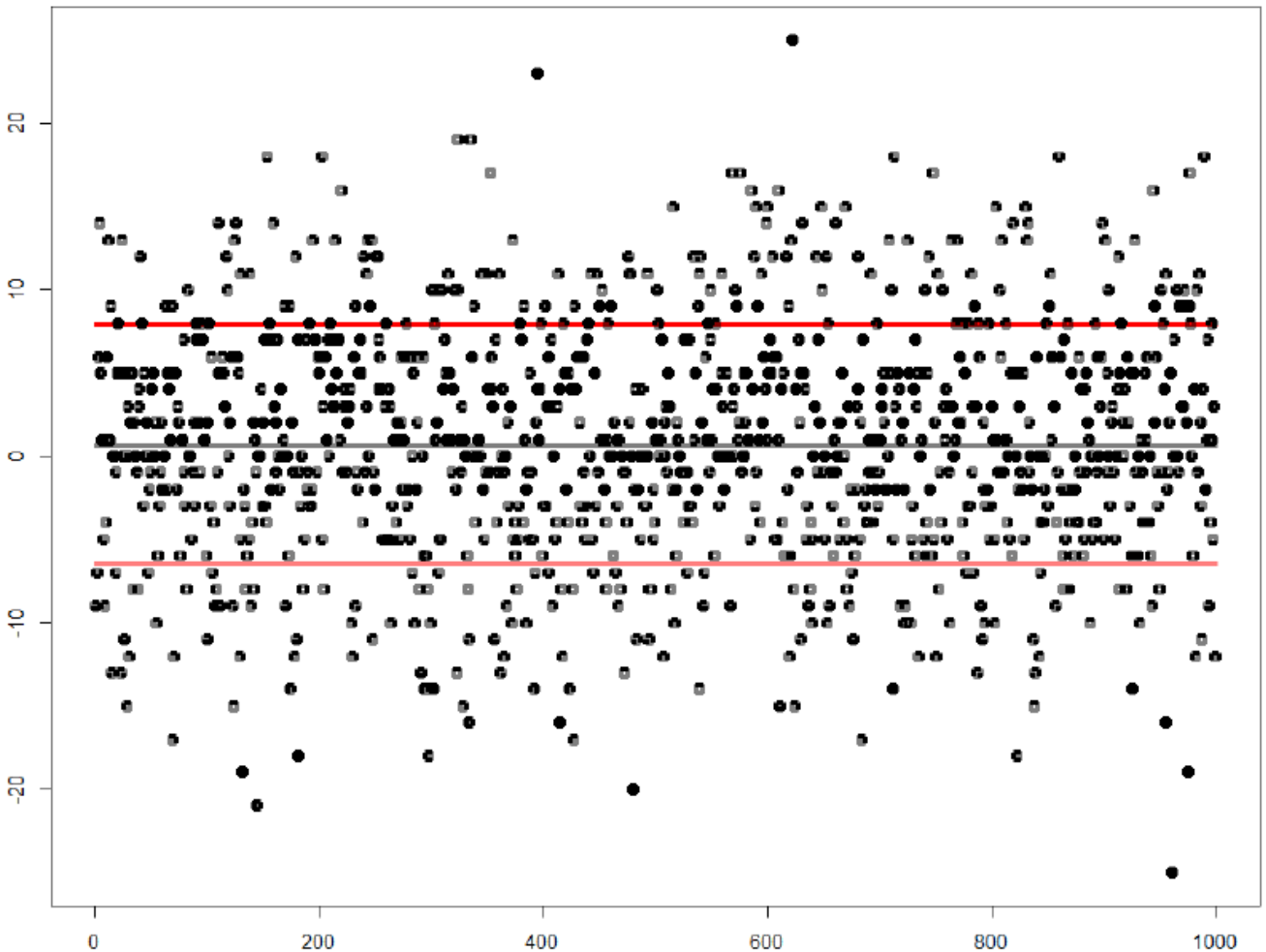
$\sigma = 79$

$N_{min} = 0$

$N_{fgrnd} = 16262$

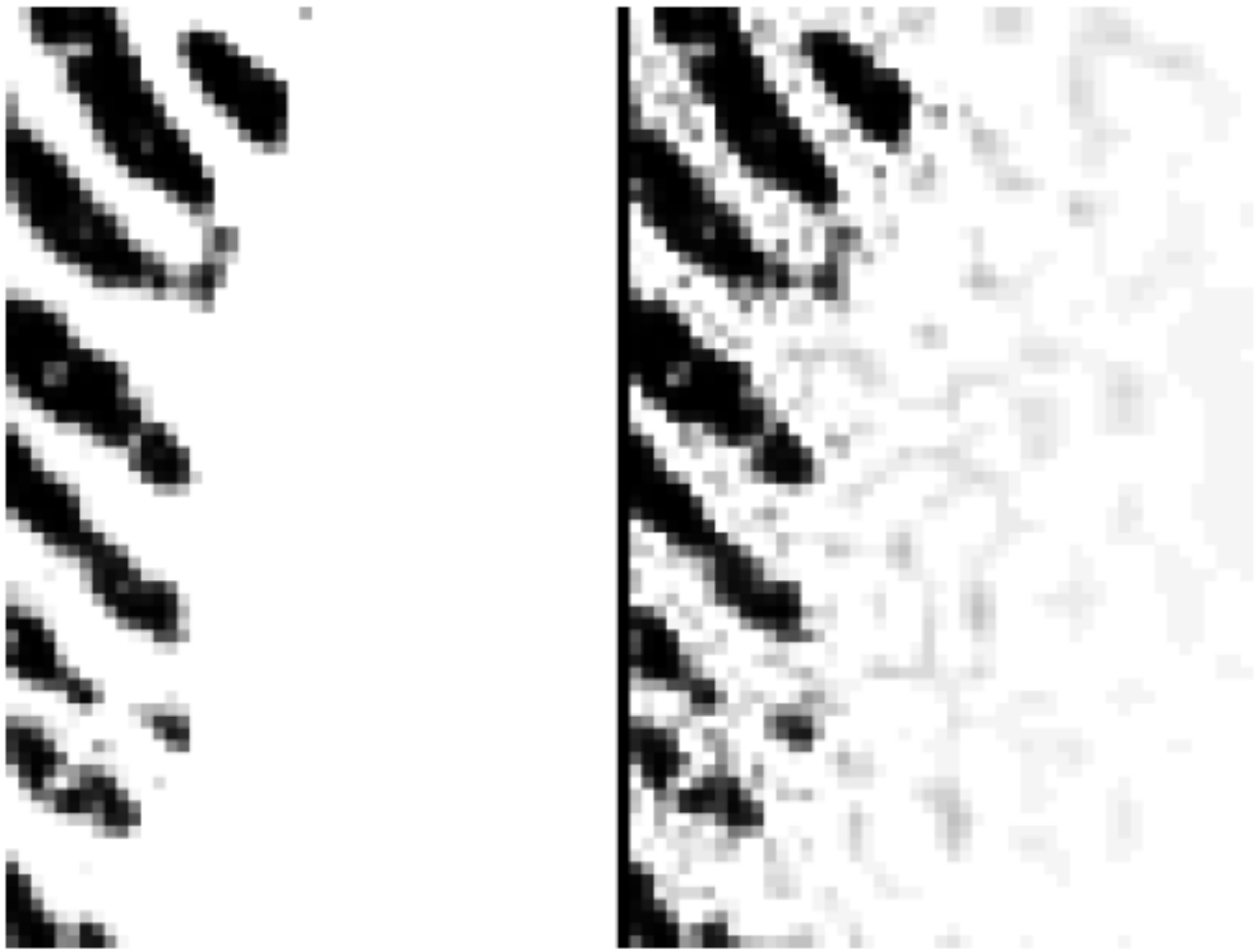
NFIQ 2.0 and WSQ compression

- Deviation between uncompressed and WSQ compressed (factor 8). 1000 images, MCYT 330 DP.



NFIQ 2.0 and WSQ compression

- Fingerprint boundary artifact at WSQ compression (factor 8). Gamma adjusted.



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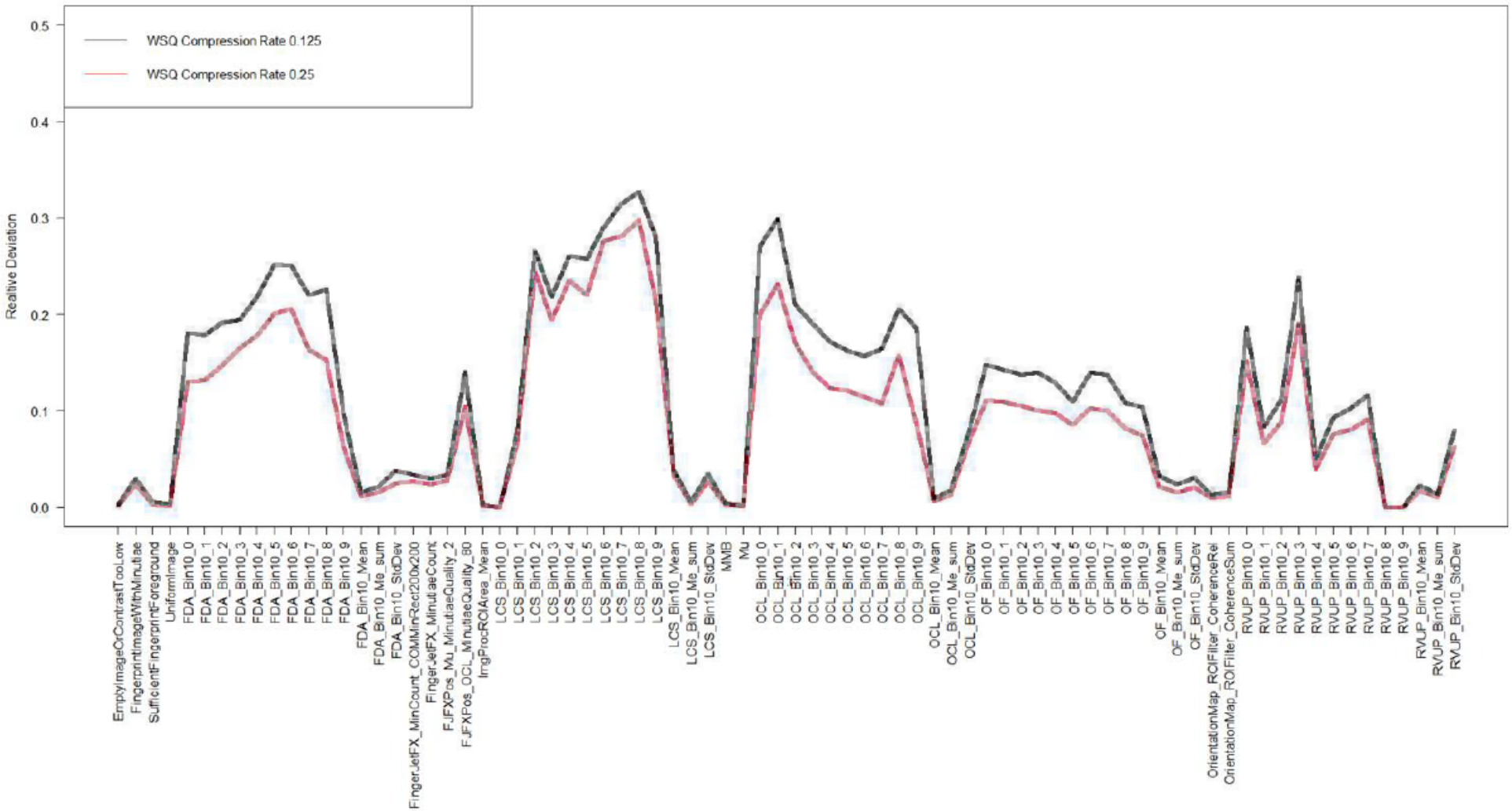

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- 29794-4 – biometric sample quality – finger image data
  - current status is 3rd Committee Draft
  - progression to Draft International Standard in May 2016
  - projected release as International Standard in 2017
- NFIQ 2.0 effectively a reference implementation of 29794-4 at this point
  - Open source, publicly available

Contact & further information

Thanks for your attention

Martin A. Olsen
Contact: martin.olsen@{cased.de; ntnu.no}

NFIQ 2.0 `nist.gov/itl/iad/ig/development_nfiq_2.cfm`

Prototype quality features `share.nbl.nislab.no/public`